U. S. ARMY

TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

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IMPROVED HELICOPTER EXTERNAL-SLING-LOAD CAPABILITY

December 1961

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RESEARCH TECHNICAL MEMORANDUM 35

Task 9R89-02-015-14

December 1961

Robert D. Powell, Jr., Project Engineer

U. S. ARMY TRANSPORTATION RESEARCH COMMAND

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CONTENTS

LIST OF ILLUSTRATIONS

SUMMARY

In the past, helicopters flying with external loads of various types have experienced situations wherein the load became so unstable that either the load had to be released or the speed had to be reduced drastically for the helicopter to recover stability. This Research Technical Memorandum presents the results of the work that the U. S. Army Transportation Research Command (USATRECOM) at Fort Eustis, Virginia, has performed to improve the capability of the helicopter to transport loads externally.

A solution to the greater part of this external-load problem was found in the design of a new sling harness, commonly referred to as a "swing". This swing, by virtue of its kinematics, raises the effective point-of-load attachment closer to the center of gravity of the helicopter. Tests were conducted on the H-21, H-34, and H-37 helicopters.

Results of tests showed that the swing system eliminated or so reduced the moments exerted on the helicopter by the external load that high forward speeds are permitted. Offset lifting and high-speed turns and stops can also be performed as routine maneuvers.

CONCLUSIONS

It is concluded that:

1. The swing sling suspended from a helicopter for transporting external cargo loads affords greater lateral and longitudinal stability than the standard sling harness.

2. The swing sling has greater capabilities than the standard sling for offset lifting and high-speed turns and stops.

3. Increased speed is possible for a helicopter carrying an external load of cargo if the swing sling rather than the standard sling is used.

BACKGROUND

The U. S. Army is continually expanding the helicopter's versatile capabilities to fulfill the many missions that are the responsibilities of the Army. The Ordnance Corps is moving missiles, missile components, guidance equipment, artillery, and tank ammunition with helicopters. The Medical Corps is using helicopters to move surgical units, laboratory equipment, medical supplies, and litter patients. The Corps of Engineers uses helicopters when bridges, roads, and buildings are being constructed. The Quartermaster and the Transportation Corps are utilizing the helicopter as they used the truck in the past, but without the limiting problems of mud, mountains, rivers, etc.

Many of the current and projected uses of the helicopter require that its load be suspended externally. In many instances, the helicopter operating with an external load has experienced instabilities severe enough to cause the helicopter to drop its load in order to maintain control and/or to prevent damage to the helicopter. In isolated cases, speed can be reduced or the load can be rerigged in an effort to solve this problem. However, these two solutions are impracticable, since they can be quite time-consuming with a resultant penalty in productivity.

A number of programs have been initiated by USATRECOM in aneffort to solve some of the more pertinent external-cargo problems. One of the most successful of these programs resulted in a minimization of the detrimental effects of unstable external loads on the helicopter's flight and on its handling characteristics. It had been noted during a particular flight test program that the helicopter lacked sufficient lateral control when its external load started to swing from side to side, like a pendulum. A change in the design of the sling harness improved this condition; however, the lateral control still was not completely satisfactory. A thorough and more basic research program to cover the overall external load-handling problems affecting stability and control of the helicopters was therefore initiated.

Contracts were awarded for the purpose of determing an optimum sling-harness design for external-cargo carrying by both tandem- and single-rotor helicopters. Emphasis was to be placed on reducing or eliminating the effect of the sling load on the helicopter's flying and handling characteristics. During the design phase, the contractor tested the improved slings on the

H-21 and the H-34 helicopters. The improved slings were then presented to the U. S. Continental Army Command (CONARC) for a minimum service test evaluation.

In the final stages of design, the USATRECOM project engineer along with the contractor's project engineer made trips to the U. S. Army Airborne and Electronics Board (A&E Board) at Fort Bragg, North Carolina, and to the Aviation Board at Fort Rucker, Alabama, to obtain comments and suggestions from pilots and crews regarding several proposed designs. A summary of their recommendations for the design of a suitable system follows:

1. Light weight.
2. No decrease in internal load capacity.
3. Positive release device.
4. Suitability for night operation.
5. Single-point suspension.
6. Easy detachability from the helicopter.
7. Minimum structural modifications to the helicopter.
8. Ability to use the helicopter for a return mission that is different from the outgoing mission.
9. Air transportability in detached form.
10. Safety of ground crew.
11. System that will not compromise primary missions of the helicopter.
12. Minimum of supporting equipment and no special tools.

An additional input to the program included the results of the user tests conducted by the U. S. Army Airborne and Electronics Board in 1959 at nine U. S. Army posts. Primarily, the test objectives were to consider standardization of external lifting hardware and helicopter hooks and to observe weight-lifting capabilities of the H-21C, H-34A, and H-37A helicopters at various altitudes and under various climatic conditions. Three hundred and forty-eight items of Army equipment and supplies were lifted externally. Some of the problems incurred during the tests were as follows:

1. High-voltage static electricity was discharged through the hooks of the helicopter.

2. Cargo hooks installed on the helicopters were unsuitable.

3. Limited-standard-type cargo net was unsuitable.

4. Field operation in dry bush areas was hazardous because of the location of the exhaust stack.

5. Down-wash beneath rotor blades of helicopters is extremely hazardous to personnel and destructive to equipment.

6. Metal clevises at the apex of the suspension sling caused extensive damage.

7. Too many individual operating techniques were employed because of the lack of proper training and technical literature.

8. Adequate air and ground crew procedures have not been standardized.

Some of these problems were solved quite easily through simple redesign, revision of technical literature, or improvements in the Army-wide training program. Other problems have required extensive research programs to find adequate solutions.

DESCRIPTION OF SWING SLINGS

SWING CONFIGURATION FOR H-21

One of the first programs initiated was the designing of a new external-cargo sling harness (shown in Figures 1a, 1b, and 1c) for use on the tandem-rotor-type helicopter. The kinematics of this design, which is referred to as a swing, are such as to locate the effective point of suspension of the cargo nearer the center of gravity of the helicopter (see Figures 2a and 2b). When the swing sling is utilized on an H-21, the effective point of suspension ranges from approximately 26 to 34 inches below the normal center of gravity, depending upon the angle of lateral swing of the external load with respect to the helicopter. When the standard sling is used, the effective point of suspension lies 134 inches below the normal center of gravity of the H-21. Although the primary consideration in the cargo swing design was to improve

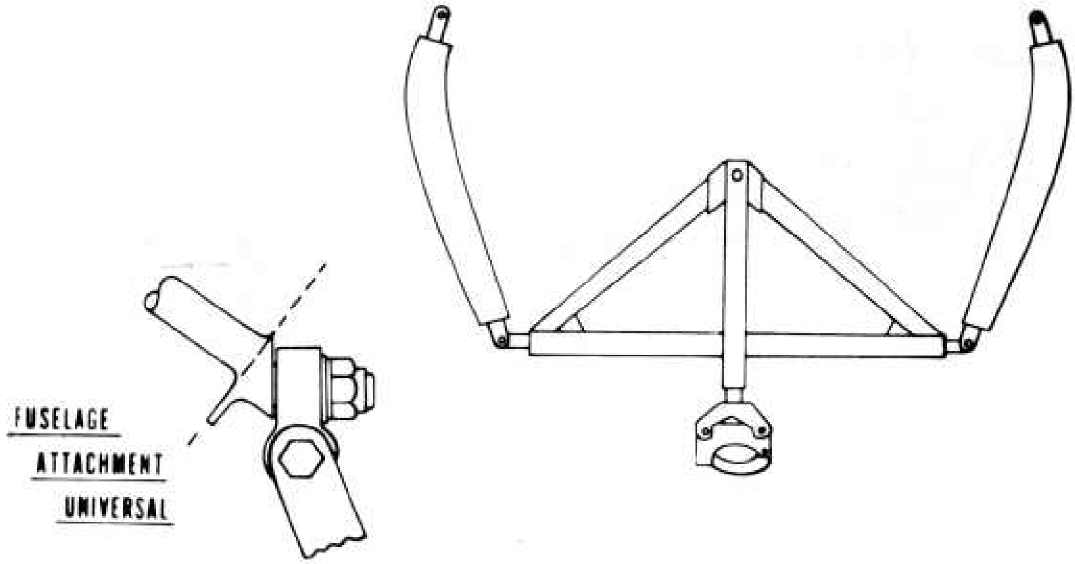


Figure 1a. H-21 Swing Configuration.

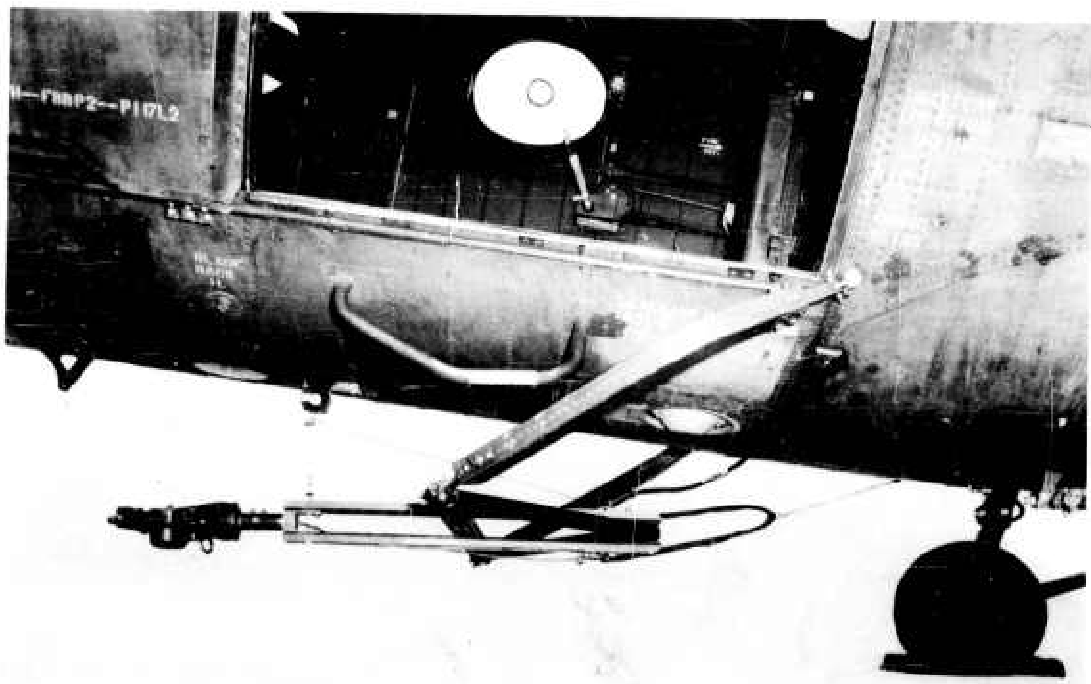


Figure 1b. H-21 With Swing Installed.

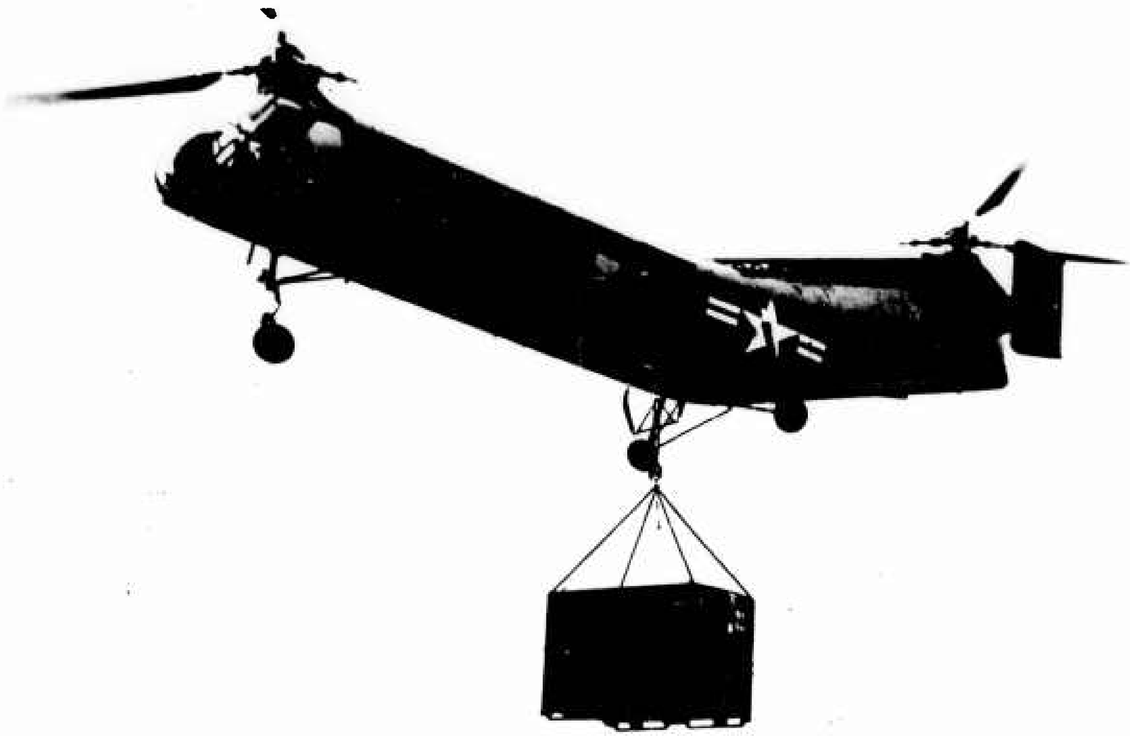


Figure 1c. H-21 With Swing Loaded.

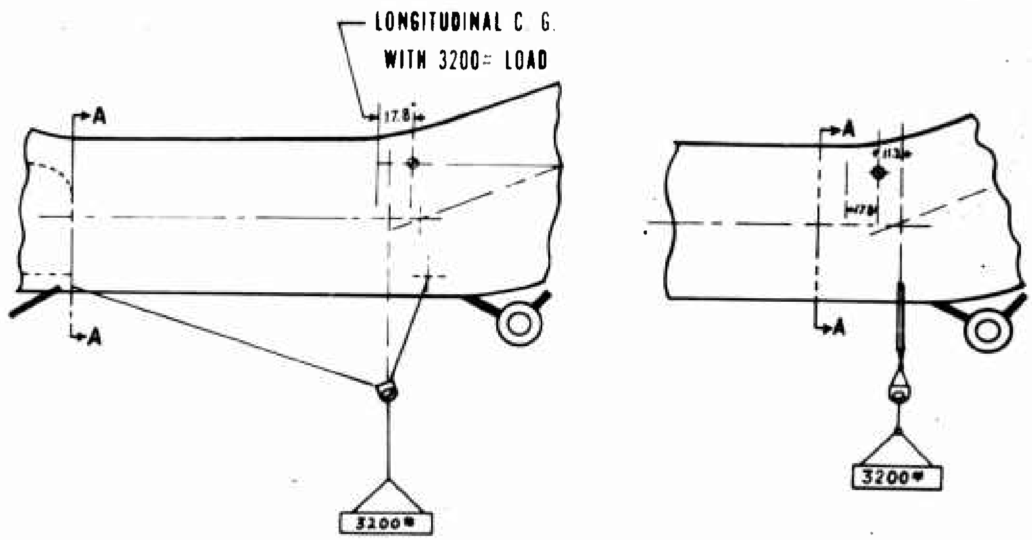


Figure 2a. Comparison (Longitudinally) of H-21 Standard Cargo Sling and H-21 Swing Sling.

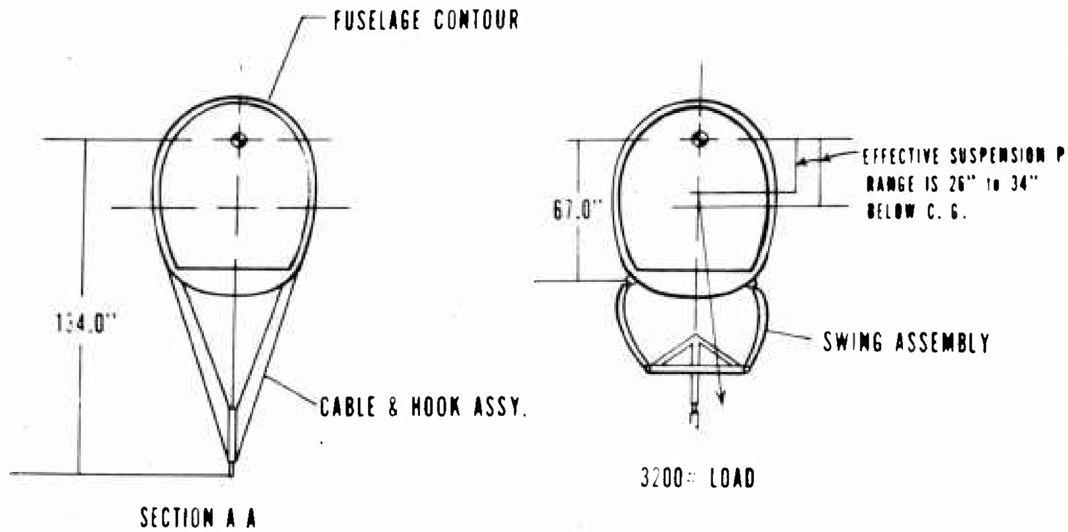


Figure 2b. Comparison (Laterally) of H-21 Standard Cargo Sling and H-21 Swing Sling.

the rolling stability of the tandem-rotor-type helicopter carrying external loads, the swing will pivot 67 inches below the center of gravity for improved longitudinal motion compared with 134 inches below the center of gravity as an effective suspension point for the H-21 standard sling. These improvements in rolling stability are due to the reduction in coupling between the lateral motion of the cargo and the rolling motion of the helicopter. Upon completion of the fabrication, proof loading, and installation of the swing design, the helicopter was instrumented and the swing was flight evaluated. The instrumentation utilized and the items recorded were as follows:

Oscillograph Recordings

Pitch rate.
Roll rate.
Roll attitude.
Longitudinal stick position.
Lateral stick position.
Airspeed.

Pilot-Observed Recordings

Manifold air pressure.
Carburetor air temperature.
Outside air temperature.

Revolutions per minute.
Airspeed.

Upon completion of approximately 10 flight hours at the contractor's facility, the swing was submitted to USCONARC for evaluation.

SWING CONFIGURATION FOR H-34

A second sling design was fabricated to improve the external cargo-carrying capability of a single-rotor helicopter. This design (shown in Figures 3a and 3b) is a "double swing" concept and was flight tested on the H-34. Again, the

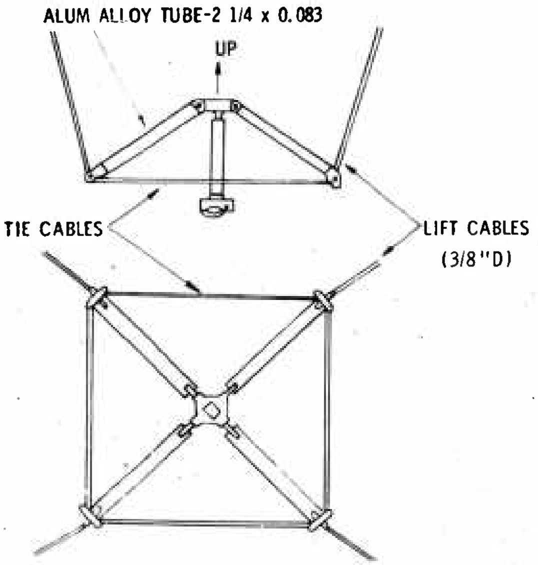


Figure 3a. H-34 Swing Configuration.

Figure 3b. H-34 With Swing Installed.

purpose of the design was to improve both lateral and longitudinal control of the helicopter when it was "slinging" an unstable load. The design load was 5,000 pounds (weight of system excluding cargo hook, 62 pounds) with an ultimate load of 5,000 times a safety factor of 2.679 (limit), or 13,395 pounds. As can be seen in Figure 4, the effective point of attachment for the standard H-34 sling is about 120 inches below the normal center of gravity. With the swing attached, this dimension is reduced to from 30.5 inches to 32.5 inches laterally and to from 16.3 inches to 18.6 inches longitudinally, the range in dimension depending upon load deflection. After completion of fabrication and proof loading, the swing was evaluated by the contractor in a manner quite similar to that performed for the H-21. Upon completion of the contractor's evaluation, the H-34 swing was also forwarded to USCONARC for a minimum service evaluating program.

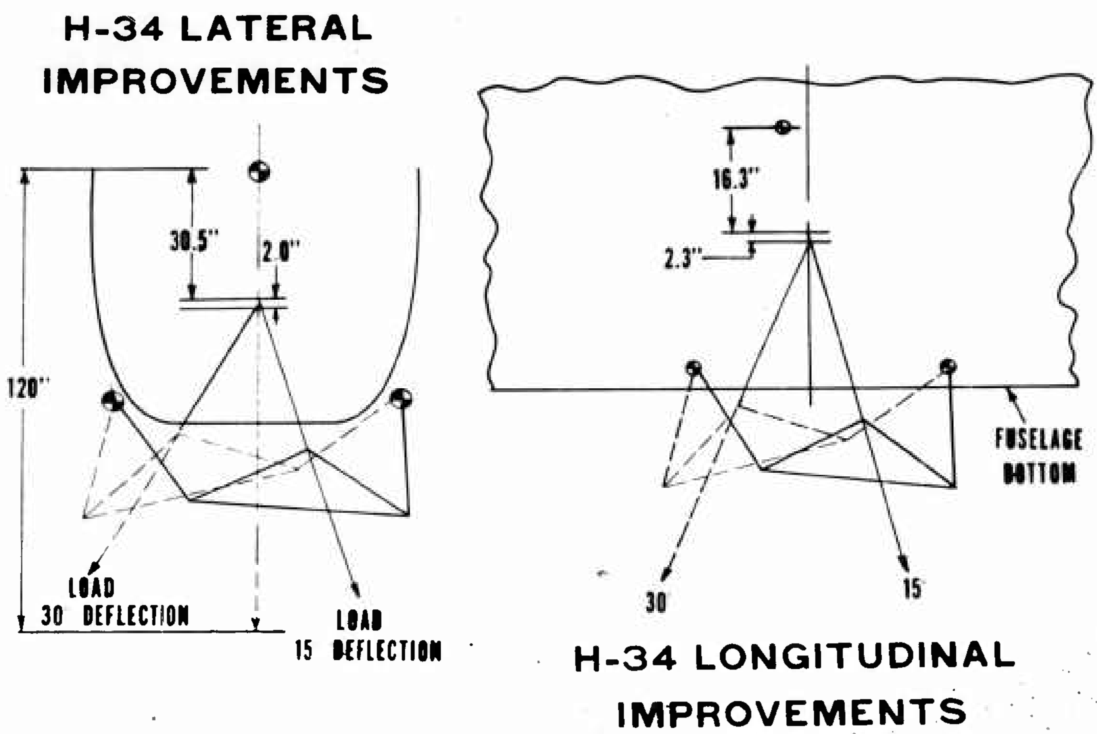


Figure 4. H-34 Swing Configuration Showing Lateral and Longitudinal Improvements.

SWING CONFIGURATION FOR H-37

A third sling design was fabricated to improve the external cargo-carrying capability of the H-37 single-rotor helicopter. The design load was 10,000 pounds with an ultimate load of 10,000 times the safety factor of 1.75 (limit), or 17,500 pounds. This design reflected the general lines of the H-34 swing design, as can be seen in Figures 5a and 5b. Figure 6a presents the improvements gained both laterally and longitudinally when the effective point of attachment was raised so that it was closer to the center of gravity of the helicopter. The effective point was raised 94.4 inches laterally and 90.4 inches longitudinally. Figure 6b is a plot showing the distance from the center of gravity of the helicopter in relation to the angle of swing. It compares the swing angles of the swing sling with those of the cargo sling currently being used on the H-37. Upon completion of fabrication, the swing was evaluated by USATRECOM at Fort Eustis, Virginia; about the same test program that was used for the H-21 was again utilized for the H-37. However, instrumentation recordings were not made for the H-37 tests.

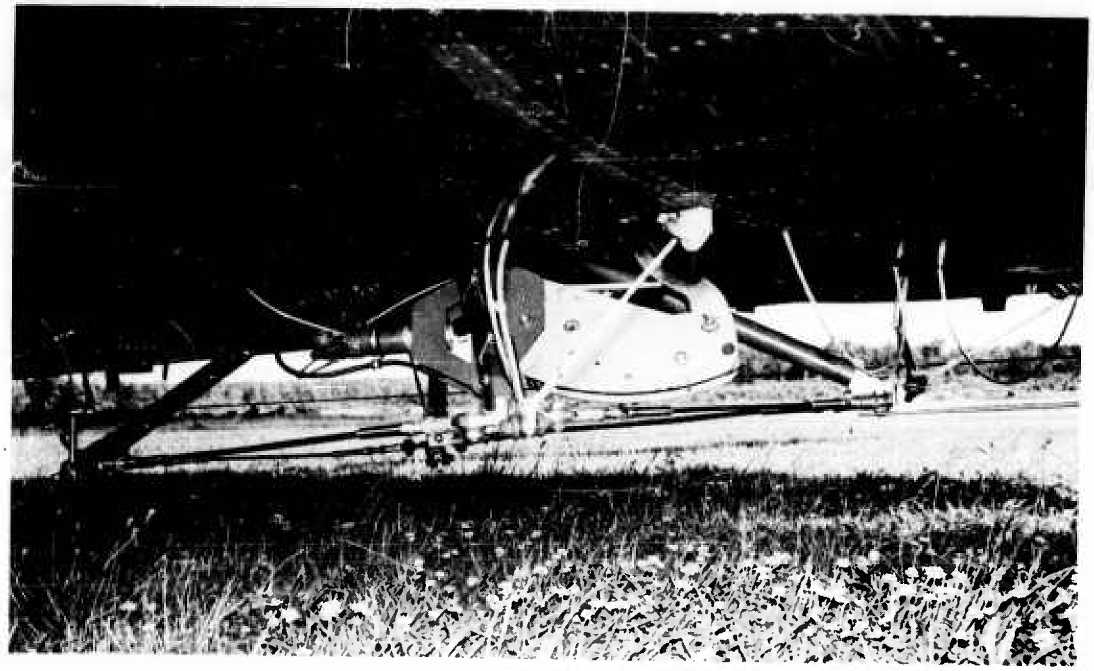


Figure 5a. H-37 With Swing Installed.

Figure 5b. H-37 With Swing Load.

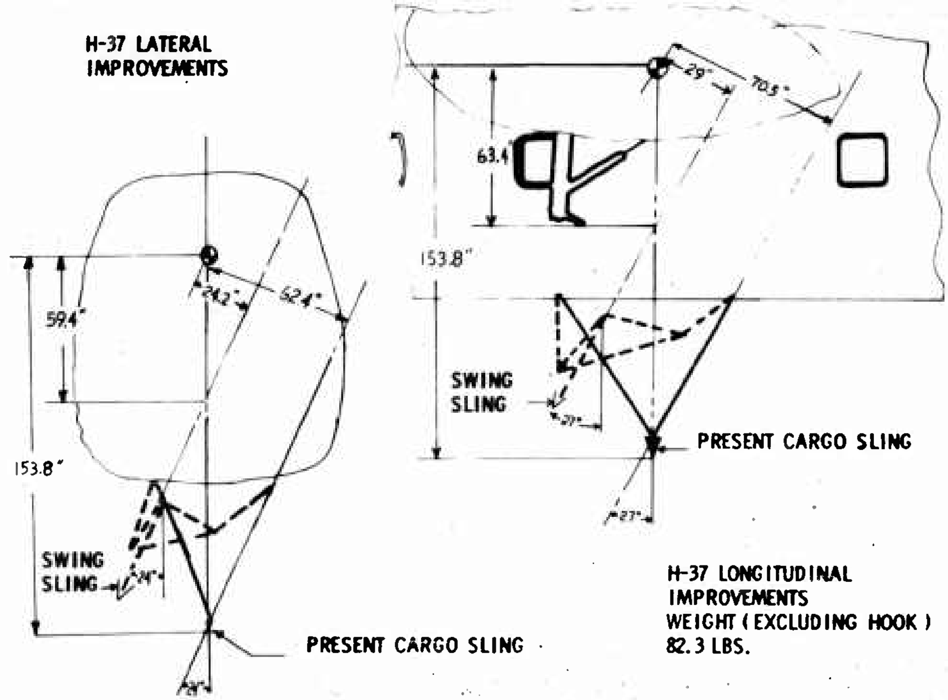
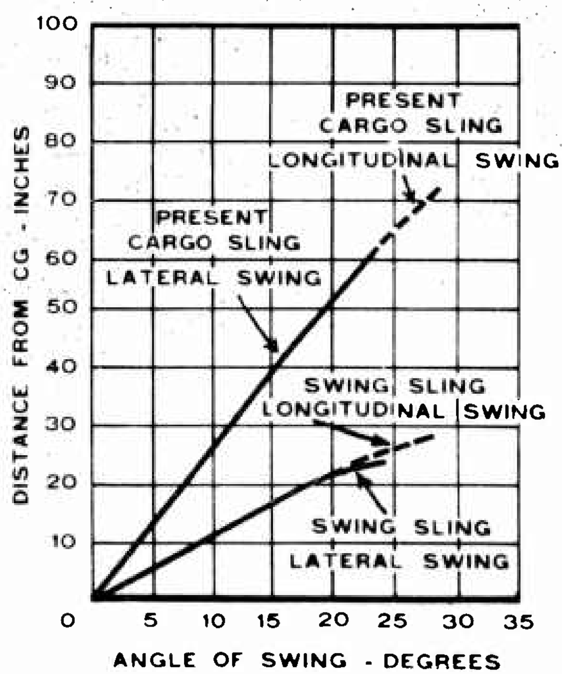


Figure 6a. H-37 Swing Configuration Showing Lateral and Longitudinal Improvements.

Figure 6b. Comparison of Swing Angles of the Swing Sling and the Standard Sling in Relation to the Center of Gravity on the H-37.



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DETERMINATION. Utilization of Swing Sling

Procedure

The swing sling was evaluated by the contractor, the Aviation Board, the Airborne and Electronics Board, and USATRECOM. External loads were flown with riser cable lengths of 0, 5, and 10 feet between the cargo and the cargo hook. The following types of loads were flown during the flight evaluation tests:

High-Density Loads

3,200-pound concrete slab
2,200-pound concrete slab
400-pound concrete slab

Low-Density Loads

1,600-pound CONEX container
600- to 1,700-pound net loads
H-21 empty rotor-blade box
Telephone poles

Equipment

2,600-pound jeep
H-13 fuselage
Ammunition boxes

Results

When the swing design was utilized in transporting external loads by helicopter, speed was increased as much as 60 to 70 percent over speeds attained when the standard sling was used. For example, speeds of 105 knots were attained when the H-34 carried a jeep on the swing. Normally, the H-34 is restricted to 65 knots with this type of load.

The advantages of the swing design are further indicated by the increased maneuvers performed with external loads that heretofore were not possible. The extent of the maneuvers is summarized below:

Stabilized Runs

At maximum velocities of 90 knots for the H-21 and 105 knots for the H-34.

Over a range of speeds of from 0 to 50 knots.

Rapid Acceleration and Deceleration (Flares)

0 to 40 knots in approximately 15 seconds.
40 to 0 knots in approximately 13 seconds.

Right and Left Sideways Flight

10 to 15 knots.

Left and Right Extreme Rolls

At 20 to 30 degrees, load oscillations are damped out in 1-1/2 to 2 cycles.

High-Speed Turns

Up to 70 knots at 30 degrees.

Offset Pickup of Loads

2 to 8 feet.

Observation.

Overall comment by pilots has been that the handling characteristics of the helicopter with the external load on the cargo swing are quite similar to the handling characteristics of the helicopter with internal cargo.

EVALUATION

The swing designs herein presented are not to be considered as fully developed prototypes but rather as designs to prove the concept and/or to determine whether improvements obtained are sufficient to warrant incorporation in future helicopters. It is believed that the total weights of the swings could be reduced somewhat and that the H-34 swing could be redesigned so that a load could be retracted in such a manner that internal cargo space would not be penalized.

Other programs being considered by the Army to improve the helicopter's external-cargo-carrying capability are shown in the Appendix.

The swing system has provided a method of significantly increasing the external-load capability of helicopters by alleviating the influence of the load on the aircraft's flying and handling characteristics. Use of the swing sling system enables suspended loads to be carried at high forward speeds; high-speed turns can be executed; and offset lifting can be performed as a routine maneuver.

BIBLIOGRAPHY

Development of Improved Cargo Sling System Incorporating Load Stabilization, Final Report on Phase I - Engineering Analysis, Vertol Report R-186 (CRD-2659), Vertol Aircraft Corporation, Morton, Pennsylvania, March 1960.

Flight Evaluation of Redesigned External Cargo Swing for H-21 Helicopters, Vertol Report R-232 (TREC 61-33), Vertol Division, Boeing Airplane Company, Morton, Pennsylvania, January 1961.

Flight Test Evaluation of an Improved External Cargo Sling System for H-34 Helicopters, Vertol Report R-237 (TREC 61-40), Vertol Division, Boeing Airplane Company, Morton, Pennsylvania, March 1961.

Flight Test Evaluation of an Improved External Cargo System for Helicopters, Vertol Report R-177 (CRD-1159), Vertol Division, Boeing Airplane Company, Morton, Pennsylvania, July 1959.

Multiple Helicopter Heavy Lift System Development Program, Final Report, Vertol Report R-178 (CRD-1359), Vertol Aircraft Corporation, Morton, Pennsylvania, August 1959.

Multiple Helicopter Heavy Lift System - Feasibility Study, Vertol Report R-136, Vertol Aircraft Corporation, Morton, Pennsylvania, October 1957.

Study and Investigation of Methods of Dissipation of Static Electricity on Helicopters, Report No. BB-1368-H (TREC 60-55), Cornell Aeronautical Laboratory, Inc., Buffalo, New York, September 1960.

APPENDIX

RELATED RESEARCH ITEMS

Following is a list of related subjects and of some of the items that either will be or have been designed, fabricated, and tested for use in transporting external cargo:

1. Universal cargo hook (being tested).

2. Static electricity elimination (in design and test).

3. Alignment system to assist pilot in maneuvering overload for pickup with minimum effort (tests completed).

4. Metal-free cargo slings (unitized load pallets or container) (tests completed).

5. Helicopter cargo nets (bulk or loose cargo) (tests completed).

6. Cargo sling adapter, metal-free (tests completed).

Tests are now underway at USATRECOM to incorporate several of these items on an H-37 helicopter as part of a flight test of a complete external-load system to determine their compatibility as a system. Primarily, the evaluation will include the cargo hook, the cargo swing, and the static electricity corona discharge system.

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Unclassified Report

Tests conducted on the H-21, H-34, and H-37 with the use of swing configurations are described and evaluated. The advantages of using

(over)

1. Helicopter Stability
2. Cargo Swing
3. Externally Loaded Helicopters
4. Slings on Helicopters

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